SEARCH FOR MAGNETIC MONOPOLES AT THE 70 GeV IPHE PROTON SYNCHROTRON

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The result of a search for magnetic charged particles at 70 GeV IPHE proton synchrotron is presented. Using the ferromagnetic trap method the upper limit of the magnetic monopole production cross-section in proton-nucleon collisions was found to be σ (95%) $\geqslant 1.4 \times 10^{-43}$ cm^2.

This article is a final publication on the experimental search for magnetic charged particles at the 70 GeV IPHE proton synchrotron with the help of the "ferromagnetic trap" method. The preliminary result with a brief description of the method is given in [1], and more detailed main features of the experiment are presented in [2]. From the analysis [3] of the magnetic charge's behaviour in metals and ferromagnetics it follows that ferromagnetic foils can be an effective trap for magnetic monopoles, even in the presence of the external magnetic field of the accelerator ($H \approx 12$ kG). The experiment was performed in two stages. In the first stage the monopoles produced in accelerator target were stored in ferromagnetic foils placed under the target. In the second stage the monopoles were extracted from the ferromagnetic traps with the help of a high pulsed magnetic field. A nuclear emulsion Br 2 of 400 micron thickness was used as a detector.

The problems of monopole trapping were considered in the papers [1, 2]. The simplicity of the trapping system permits us to have 100% efficiency of monopole trapping and simultaneously to use several operating targets of the accelerator. The trap method used has no serious background problems and it allows us to expose the same ferromagnetic foils for several months. In refs. [1, 2] the detection system with a pulsed magnet of ~ 220 kG was used. This system makes it possible to detect monopoles of both signs. About 35% of the exposed ferromagnetic foils was subject to the action of the 300 kG magnetic field in the new magnet design [4]. The long length of this magnet and, as a consequence, the good uniformity of the magnetic field along the magnet axis permits us to place the ferromagnetic foils at such a distance from the detector that the monopoles could obtain essentially more energy than in the case when the 220 kG magnet was used. In fig. 1 a schematic drawing of the new detection system is shown. The ferromagnetic foils were placed at the edge of the

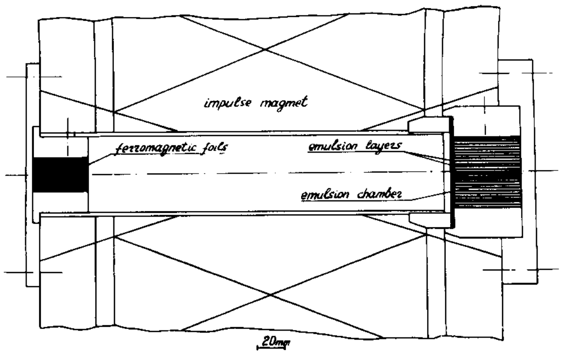

Fig. 1.

magnet at a distance of 13 cm from the centre. At the opposite edge of the magnet two transverse layers of emulsion 80 mm in diameter were installed. Just behind it was the emulsion chamber of $55 \times 45 \times 30$ mm^3. This system can only detect negative magnetic charges. (In ref. [1] in fig. 1 it was shown by mistake that g^+ monopoles could come into the sample.) Knowing the Hz distribution along the magnet axis and the properties of the ferromagnetic foils [3] it is possible to calculate the energies which monopoles with charge $g = 68.5\,e$ will reach on the 26 cm path in the magnet. These energies were found to be 21 GeV, 41 GeV and 58 GeV for experiments with permalloy 79 HM, permalloy 50 H and permendure, respectively. The monopoles would lose this energy in 1-3 cm of nuclear emulsion. This means that tracks of very high ionization (about 5000 times greater than the ionization of a relativistic proton) might be observed not only inside the two transverse layers of emulsion but also inside those layers of the emulsion chamber for which the trajectory of the monopoles lies in the plane of the field of vision of the microscope. To cover the possibility of an anomalous interaction of the monopoles with the material it is assumed that the 200 - 300 kG magnetic field is not sufficient to extract the monopoles from the ferromagnetic foils. Therefore in addition some of the exposed foils were placed in a pulsed magnetic field of $\sim$ 800 kG. In this experiment the detector consists of two layers of nuclear emulsion placed near the ferromagnetic foils.

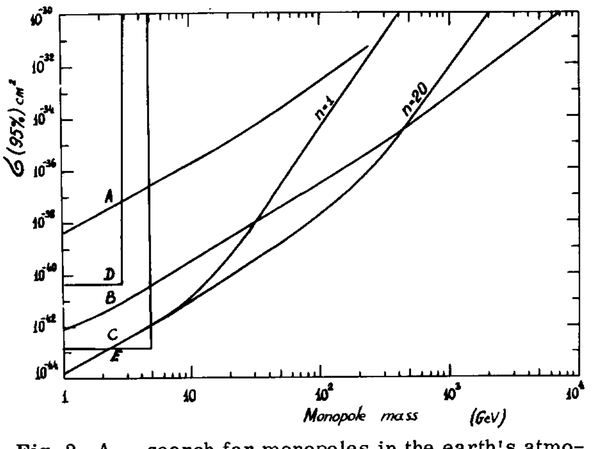

Fig. 2. A - search for monopoles in the earth's atmosphere [5], B - search for monopoles in magnetic oceanic minerals [6], C - search for monopoles in lunar matter [7], D - experiments on the 30 GeV accelerators [8], E - results of the present work.

In scanning the emulsion layers no tracks were found crossing both transverse layers with an ionization noticeable greater than that of a relativistic proton. If full transparency of the Al target nucleus is assumed the result of this experiment gives the following upper limit for the cross-section of the monopole production in the reaction $p + N \to p + N + g^+ + g^-$; $\sigma(95\%) \leq 1.4 \times 10^{-43}$ cm^2. This result is represented in fig. 2 by curve E. If the target nucleus is not assumed to be transparent, the effective number of nucleons in the nucleus will be $A^{2/3} = 9$ and in this case

$$\sigma\,(95\%) \leq 4.2 \times 10^{-43}\ \mathrm{cm}^2 .$$

As the force retaining the monopoles on the ferromagnetic surface depends logarithmically on the magnetic charge [3], this result covers monopoles with larger charges. The results of the experiment also cover diones.

It should be noted that it is better to consider σ (95%) not as a cross-section for monopole production in general, but as a cross-section for monopoles that are free at a large distance from the production point.

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